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(54) **Aluminium sheet and method for its manufacture.**

(57) The invention relates to the manufacture of a soft, highly deformable SSF aluminium sheet with a composition belonging to the AA 5000 series of Al-Mg alloys with a Mg content of over 0.8% Mg, suitable for deforming purposes such as, for example, the manufacture of bodywork parts for cars by pressing. The grain size of the sheet after recrystallization annealing at finished thickness is less than 50 µm. This recrystallization annealing is performed in a continuous annealing furnace with a heating rate of over 50 °C/s, followed by quenching.

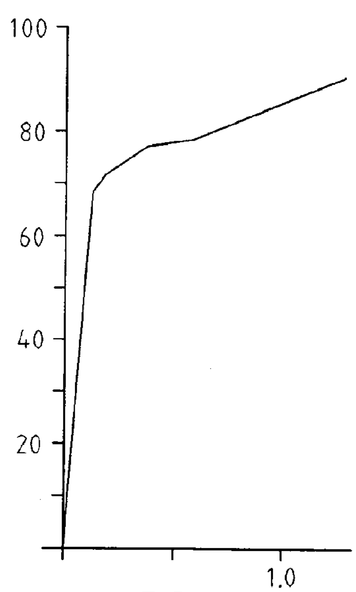

FIG. 1D

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The invention relates to a method for the manufacture of soft, deformable SSF aluminium sheet having a composition belonging to the known AA 5000 series of Al-Mg alloys with a Mg content of over 0.8% Mg, and to sheet of this type. The sheet is suitable for deforming purposes such as, for example, the manufacture of bodywork parts for cars by pressing.

In this specification, in relation to the aluminium sheet of the type described above, 'soft' is understood to describe the supply condition of the sheet. Within the framework of this application, the supply condition 'soft' relates to the condition following recrystallisation annealing, which may sometimes be followed by a light post-treatment such as flattening. In its 'soft' condition, the material is ready for shaping by deformation involving curvature in two planes.

In this specification, 'sheet' is understood to be not only sheets obtained by cutting off, but also strip-shaped sheet still on coils until cut off.

In this specification, 'SSF' (Stretcher Strain Free) is used in its meaning normal in this art, i.e. to define sheet that, in cold plastic deformation, remains free of type A Stretcher Strain marks, so-called Lüder lines. These grain-like unevenesses in the surface of the material occur when the material flows and are not acceptable for visible outer bodywork parts because they remain visible after painting.

Lüder lines are also known in steel. For this reason, deformation steel is usually temper rolled. This is not customary with aluminium because this cold work-hardening reduces deformability to a significant degree.

In their soft condition Al-Mg alloys of the 5000 series are very susceptible to Lüder lines. With Al-Mg alloys the conventional way to make material unsusceptible to type A Lüder lines is to ensure that the grain size of the material is greater than 50 μm at finished gauge. With a grain size of over 50 μm the risk of type A Lüder lines is then low. This is achieved by recrystallization annealing at a gauge greater than the finished gauge, so-called intermediate annealing. Thereafter, in a second cold rolling stage the material is brought to finished gauge with a precisely determined reduction in the range of 15 to 20% and is again recrystallization annealed, so-called final annealing. If reduced more the grain size is smaller than 50 μm and Lüder lines occur. If reduced less the grain size of the material after recrystallization is so great that the so-called orange-peel phenomenon occurs on pressing. All in all this classic way of manufacturing SSF Al-Mg sheet is a rather critical procedure which can easily lead to complaints from sheet users about Lüder lines or orange-peel effects after they have processed the sheet.

US-A-4151013 describes AA 5000 Al-Mg alloy SSF sheet. The document discusses the disadvantages and failure of a process for dealing with type A lines involving annealing at 500°C (or 300°C) then quenching in cold water and finally lightly rolling or roller-levelling. The new process proposed by the document includes a brief annealing followed by a slight but significant stretching, of about 0.5%. The annealing is said to involve quenching at rates slower than a cold-water quench. The details of the specific process of continuous annealing described imply that a very rapid heating rate during annealing was not used. The grain size of this product is not mentioned.

GB-A-2024861 describes an Al-Mg alloy SSF sheet having a content of Zn (0.5 to 2.0%) which places it outside the AA 5000 series. The sheet has grain size of less than 50 μm. Comparative tests in this document suggest that a AA 5000 sheets having a grain size of less than 50 μm are not SSF.

EP-A-259700 proposes that, after a T4 solution heat treatment and straightening of Al-Mg alloy containing 2 to 6% Mg, a post-heat-treatment involving rapid heating and cooling is performed; this post-heat-treatment is an artificial ageing, not a recrystallization heat treatment. The alloy is of the so-called heat-treatable type. The alloys of the present invention are not suitable for T4 treatment.

US-A-4021271 describes a different kind of aluminium product containing 2-9% Mg, and also containing 0.75-5% aluminide-forming transition elements such as Fe, Co, Ni, whose function is cause formation of fine aluminide particles in casting. On annealing, the cold-worked structure recrystallizes to give an ultra-fine structure with an average grain size of less than 15 μm. Continuous and batch annealing is mentioned, but not heating or cooling rates are given. The present invention excludes aluminium products of this kind in which aluminide-forming elements are present in order to achieve a fine grain size.

The object of the present invention is to provide an improved SSF Al-Mg sheet material and an improved method for its manufacture.

The invention in one aspect is set out in claim 1. Preferably the grain size of the sheet after recrystallization annealing at finished gauge is less than 40 μm. In this specification, the grain size is understood to be the average grain diameter according to ASTM E 112.

In the invention, the aluminium sheet is recrystallization annealed at finished gauge in a continuous annealing furnace with a heating rate in the heating section of the continuous annealing furnace of over 50°C/s and preferably of over 80°C/s, whereafter the sheet is rapidly quenched. Preferably the aluminium sheet is warmed up homogeneously in the continuous annealing furnace by means of inductive heating.

Although an intermediate recrystallization in cold rolling may be performed, it is preferred that the sheet is recrystallization annealed solely at finished thickness.

Surprisingly it has been found that continuously annealed material made by the method of the invention, of which the grain size is smaller than 50 µm, does not display Lüder lines on cold plastic deformation. Up to now specialists have generally assumed that continuously annealed material would not be Stretcher Strain Free on account of the small grain size which is obtained in continuous annealing.

The invention also provides soft, recrystallization-annealed, deformable SSF aluminium sheet as set out in claim 8.

The invention has many advantages. First of all the deformability of the sheet in accordance with the invention is excellent and the elastic limit is high. As a result of the small grain size the material does not display any orange-peel effect on deformation, so that in the deformed zones a very smooth surface appearance is obtained. Secondly, because of the very short annealing time at the surface of the sheet, practically no oxide layer forms on the sheet so that no discolorations occur and fewer problems arise during pressing. Also, in the case of continuous annealing after cold rolling, the rolling oil gives far less problems because no spots are left as a result of partial combustion. When there is no intermediate annealing, energy consumption is much lower and the throughput time of the product much shorter.

The method of production of sheet of the invention is generally in accordance with conventional principles, except as specified, for aluminium alloy sheet of this type, which is hot-rolled to a suitable thickness for the subsequent cold-rolling.

Example

Trials were conducted with AA 5051 A material; this is a material from the AAA 5000 series containing 1.8% Mg, and standardized in DIN as AlMg 1.8. Fe + Ni + Co is less than 0.50%. The material was cold rolled with 75% reduction from an initial thickness of 4 mm to a final thickness of 1 mm.

The following samples were manufactured:

Sample	Intermediate annealing	Final annealing1)	Annealing method3)	Figure
A	-	x	batch	1A
B	x	x2)	batch	1B
C	x	x2)	continuous	1C
D	-	x	continuous	1D

Notes:
1) at finished gauge
2) reduction took place following intermediate annealing, of 15% to 20%
3) method for final annealing

In the final annealing, the heating rate in the batch method (samples A and B) was 40° C/hour, and for the continuously annealed samples (C and D) 80° C/s. The heating temperatures and holding times were 1 hour at 400° C in the batch annealing and 1 to 15 seconds at 440° C in the continuous annealing. In the continuous annealing, the quenching was by water with a cooling rate of 400 ° C/s (in the invention, a minimum cooling rate in the quenching of 200° C/s is preferred).

Tensile tests were conducted, the results of which are given in accompanying Figures 1A to 1D and in the Table below.

Figures 1A to 1D show the transition from the elastic to the plastic part of the stress/strain graphs of the samples A to D.

It was found that only sample A has a distinct yield point (horizontal plateau); for the specialist this is an indication that Lüder lines can occur on cold plastic deformation.

Sample B, a material manufactured in accordance with the state of the art, does not have any horizontal plateau. However, horizontal plateaux were also not found with samples C and D, which embody the invention. Sample D which was not subjected to intermediate annealing is the best embodiment of the invention.

Table

Sample	Elongation at break[1)] %	Lüder lines type A[2)]	Grain size µm	Erichsen values mm[3)]
A	22-23	x	40	9.6/9.6/9.6
B	20-21	-	100	9.5/9.6/9.6
C	20-21	-	45	10.3/10.2/10.2
D	25-28	-	30	10.3/10.3/10.3

Notes:

1) with an initial measuring length of 50 mm

2) in tensile test

3) for a sample thickness of 1.2 mm.

The Table shows that in particular continuous annealing without intermediate annealing (Sample D) produces a high elongation at break.

In order to ascertain with certainty the presence of type A lines, a tensile test was carried out in which a strip with a polished surface was pulled perpendicularly to the rolling direction. The Table shows that, in this test, type A lines only occur with sample A. The grain size of sample A is smaller than 50 µm.

As a result of the intermediate annealing the grain size of sample B is greater than 50 µm, while the grain size of samples C and D is smaller than 50 µm.

Finally the table shows that with continuous annealing a significant 7% higher Erichsen value is achieved with the same sheet gauge.

Practical deformation trials were conducted. A car body part was made on an industrial press from sheets of the samples B, C and D. No Lüder lines occurred but the surface of the component made from samples C and D was much smoother than that made from sample B. The most pronounced difference was in the most greatly deformed zones of the component.

Claims

1. Method for the manufacture of soft, deformable SSF aluminium sheet which has the following composition, in percent by weight:

Mg	0.8 - 5.6 %
Si	0.4 % max
Fe + Ni + Co	0.75 % max in total
Cu	0.2 % max
Mn	1.0 % max
Cr	0.35 % max
Zn	0.25 % max

Other elements 0.05 % max each and 0.15 % max in total
remainder Al,

which method comprises the steps of
(i) cold rolling of sheet, optionally with intermediate annealing, to finished thickness,
(ii) recrystallization annealing at finished thickness in a continuous annealing furnace with a heating rate of over 50 ° C/s,
(iii) quenching the sheet after the annealing step (ii),
steps (i) to (iii) being such that the grain size of the sheet after step (iii) is less than 50 μm.

2. Method according to claim 1 wherein the content of Fe + Ni + Co is not more than 0.50% in total.

3. Method according to claim 1 or claim 2 which does not include any stretching of the sheet following step (iii).

4. Method according to any one of claims 1 to 3 wherein said heating rate in step (ii) is over 80 ° C/s.

5. Method according to any one of claims 1 to 4 wherein the aluminium sheet is heated homogeneously in the continuous annealing furnace by inductive heating.

6. Method according to any one of claims 1 to 5 wherein the sheet is cold rolled without intermediate annealing, recrystallization annealing being conducted solely at finished thickness.

7. Method according to any one of claims 1 to 6 wherein said grain size after step (iii) is less than 40 μm.

8. Soft, recrystallization-annealed, deformable SSF aluminium sheet have the following composition, in percent by weight:

Mg	0.8 - 5.6 %
Si	0.4 % max
Fe + Ni + Co	0.75 % max in total
Cu	0.2 % max
Mn	1.0 % max
Cr	0.35 % max
Zn	0.25 % max

other elements 0.05 % max each and 0.15 % max in total
remainder Al,
and having a grain size of less than 50 μm.

9. Aluminium sheet according to claim 8 wherein said grain size is less than 40 μm.

10. Aluminium sheet according to claim 8 or claim 9 wherein the content of Fe + Ni + Co is not more than 0.50% in total.

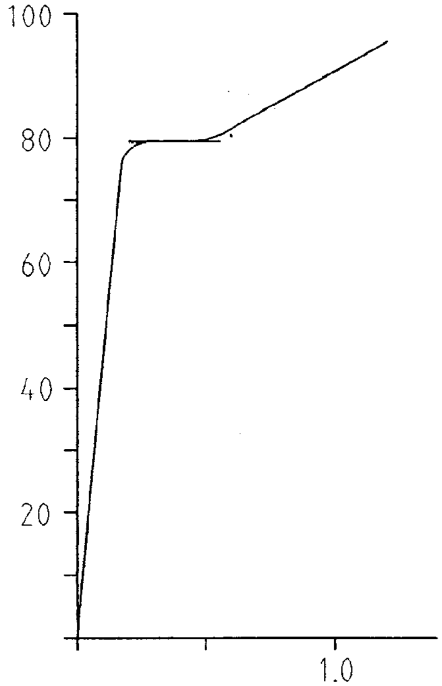

FIG. 1A

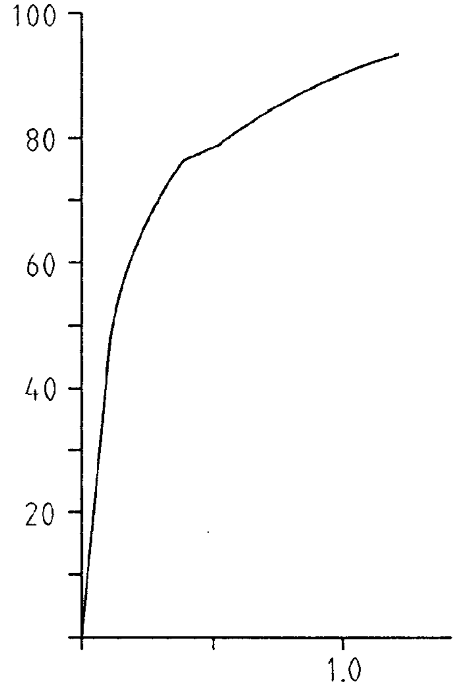

FIG. 1B

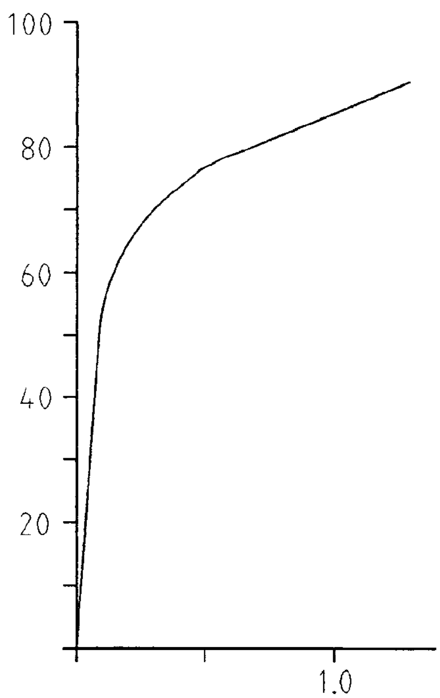

FIG. 1C

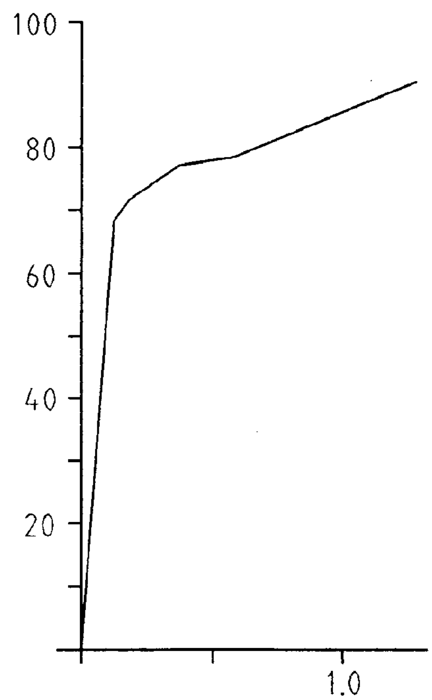

FIG. 1D

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EUROPEAN SEARCH REPORT

Application Number

EP 92 20 0925

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 410 (C-540)28 October 1988 & JP-A-63 149 348 (KOBE STEEL LTD) 22 June 1988	8-10	C22F1/047 C22C21/06
A	*ABSTRACT* ---	1	
D,A	EP-A-0 259 700 (SKY ALUMINIUM CO. LTD) * claim 1; figure 1; example 1 * ---	1,8	
A	EP-A-0 385 257 (SUMITOMO LIGHT METAL INDUSTRIES LIMITED) * claim 1; example 1 * ---	1,8	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 423 (C-638)20 September 1989 & JP-A-1 162 753 (KOBE STEEL LTD) 27 June 1989 * abstract * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 504 (C-653)13 November 1988 & JP-A-1 201 449 (KOBE STEEL LTD) 14 August 1989 * abstract * ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	DE-A-1 954 751 (OLIN MATHIESON CHEMICAL CORP.) * claims 1,2 * ---	1	C22F C22C
D,A	GB-A-2 024 861 (SWISS ALUMINIUM LTD.) * claims 1,4,6 * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 334 (C-742)18 July 1988 & JP-A-2 122 054 (KOBE STEEL LTD) 9 May 1990 * abstract * -----	8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04 JUNE 1992	GREGG N.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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